Climate-related changes on New England lakes and rivers during the last two centuries

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Purpose

- Test for significant changes over time in historical water-resources data (lake ice, river ice, and river flow)
- Quantify the magnitude of changes
- Look at relation between lake and river data and meteorological data (air temperature and precipitation)

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Lake ice-out dates

- Typical definition
  - The date that ice cover completely leaves a lake

Not quite out

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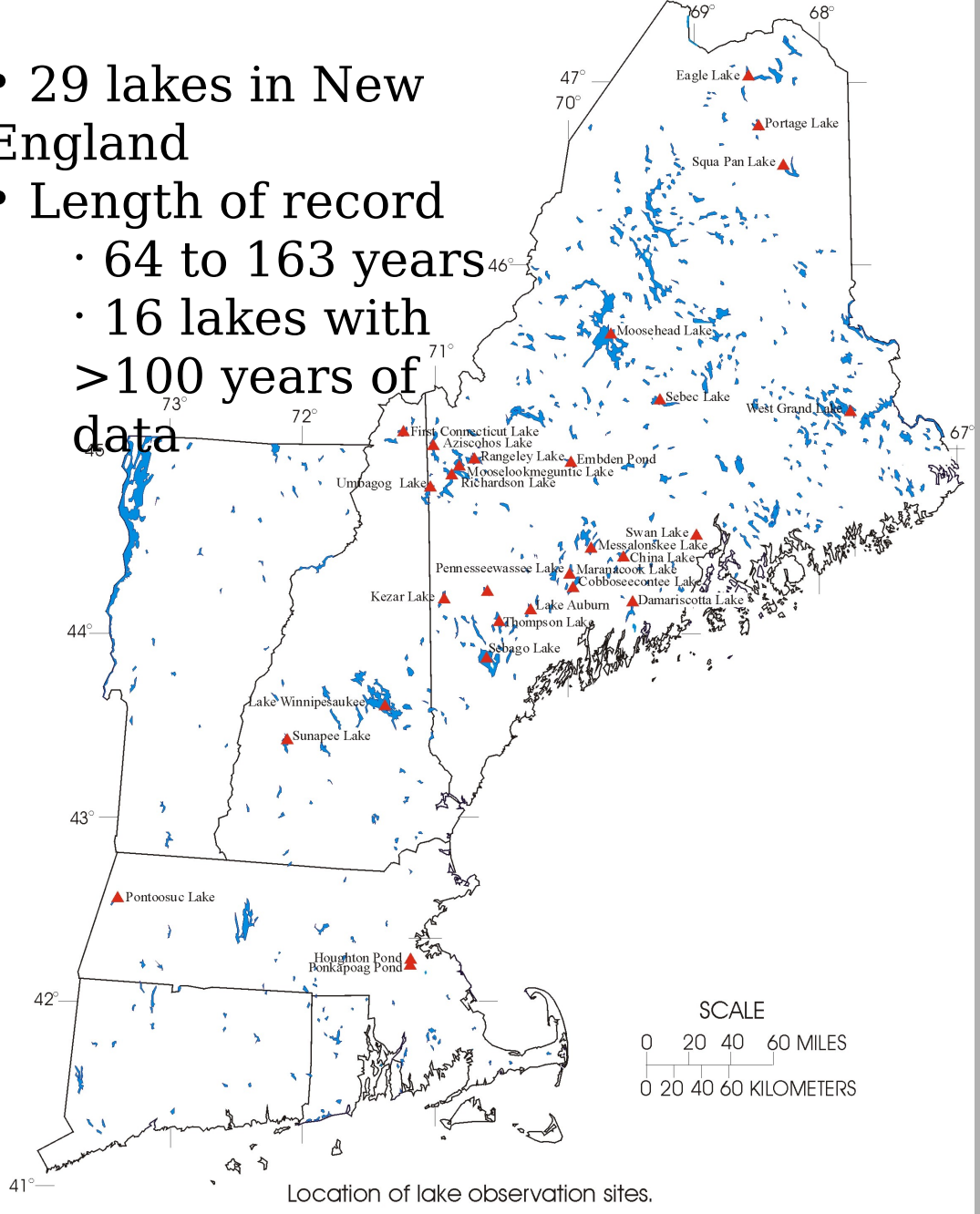
- 29 lakes in New England
- Length of record
  - 64 to 163 years
  - 16 lakes with >100 years of data



Location of lake observation sites.

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Damariscotta Lake Ice-Out Dates

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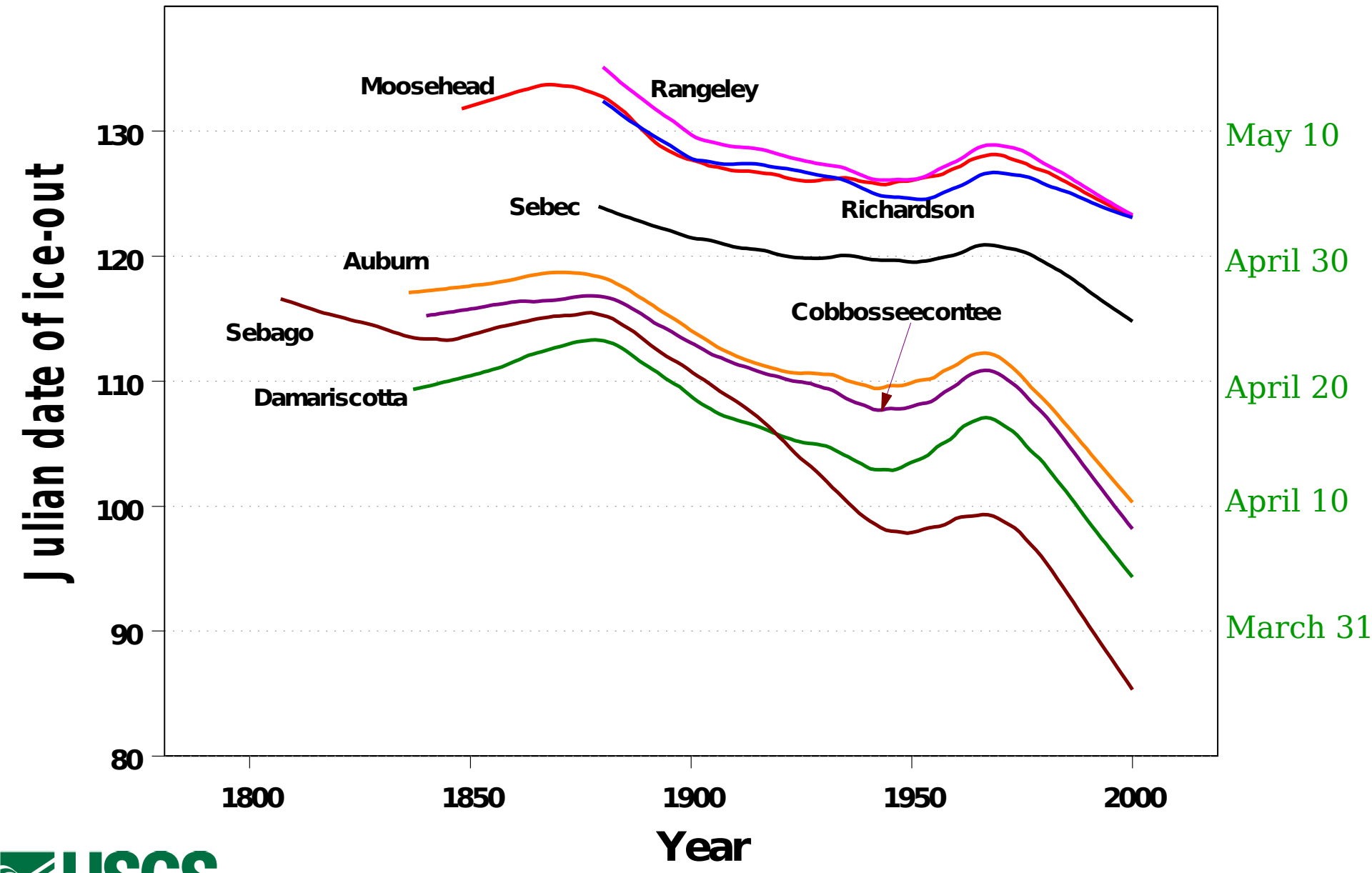
Smoothed ice-out dates for 8 selected lakes in New England



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Lake ice-out dates

- Significantly earlier ice-out dates at 19 out of 29 lakes ($p<0.1$)
- Significantly earlier ice-out dates at all 5 lakes with > 150 years of data ($p<0.0001$)
  - Damariscotta, Sebago, Auburn, Cobbosseecontee, Moosehead
- No significantly later ice-out dates ($p<0.1$)

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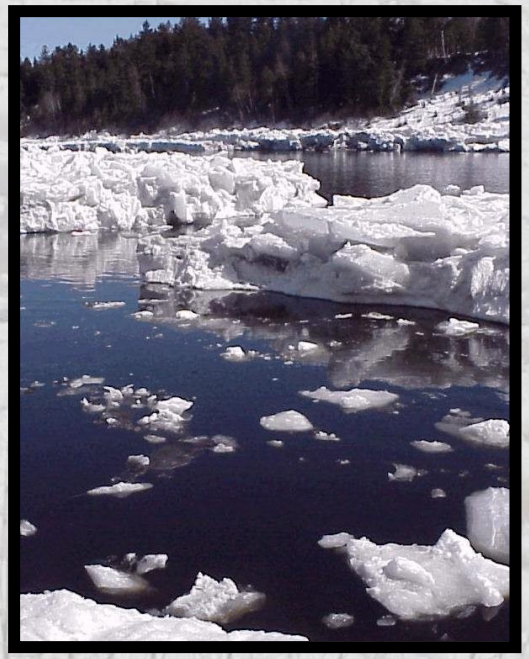
New England River Ice

- Changes in the number and timing of days of ice-affected flow on northern New England rivers



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New England River Ice

- 16 rural, unregulated rivers
- Few significant changes in the first fall dates of ice-affected flows
- Earlier last spring date of ice-affected flow
  - 11 days earlier, 1936-2000
- Number of days of ice-affected flow decreased significantly at 12/16 rivers

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Annual and monthly mean flows

- Evidence of changes in timing of flows?
- 27 rural, unregulated streamflow gaging stations
- Trends over time in the magnitude of annual and monthly mean flows

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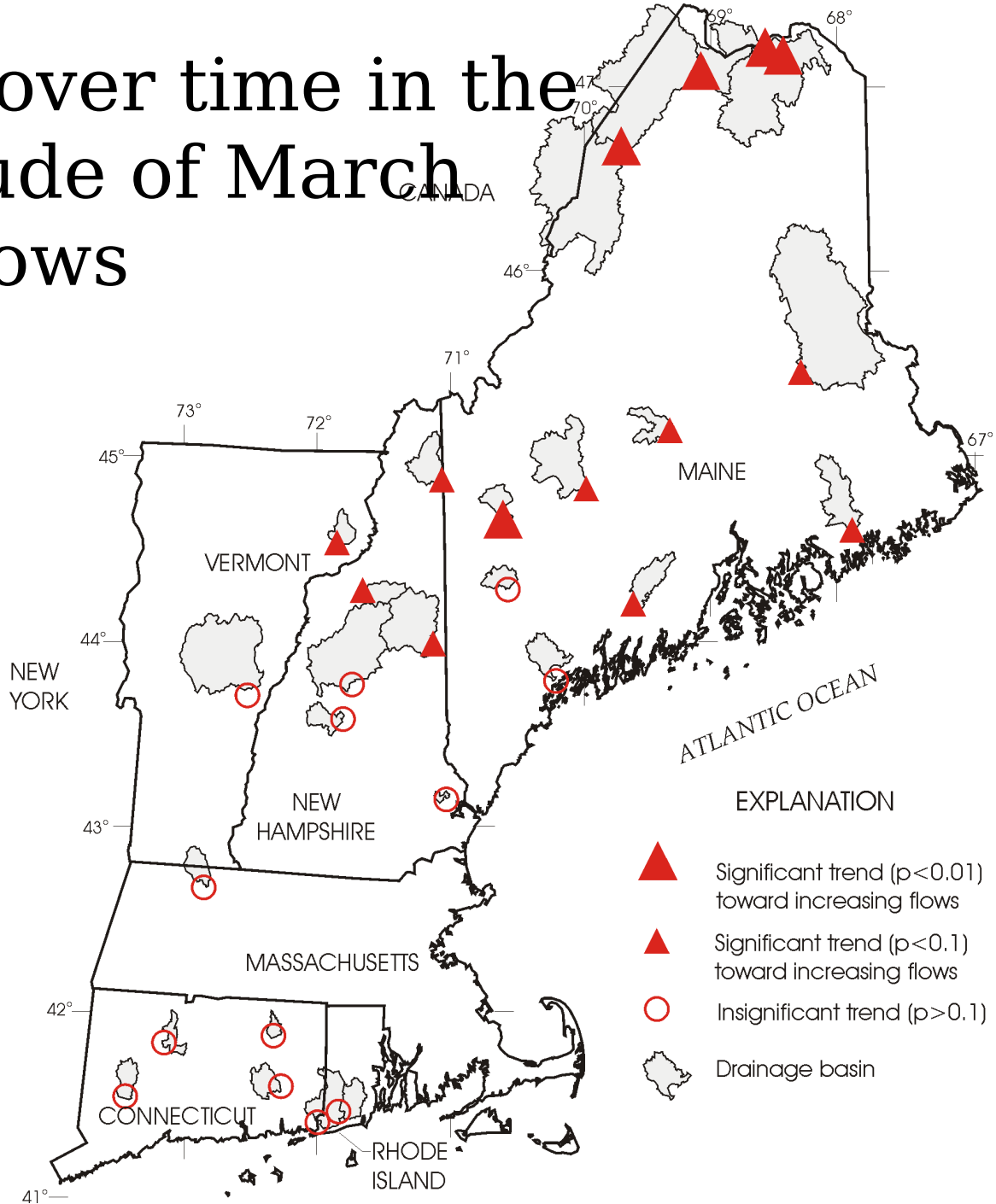
Trends over time in the magnitude of March mean flows



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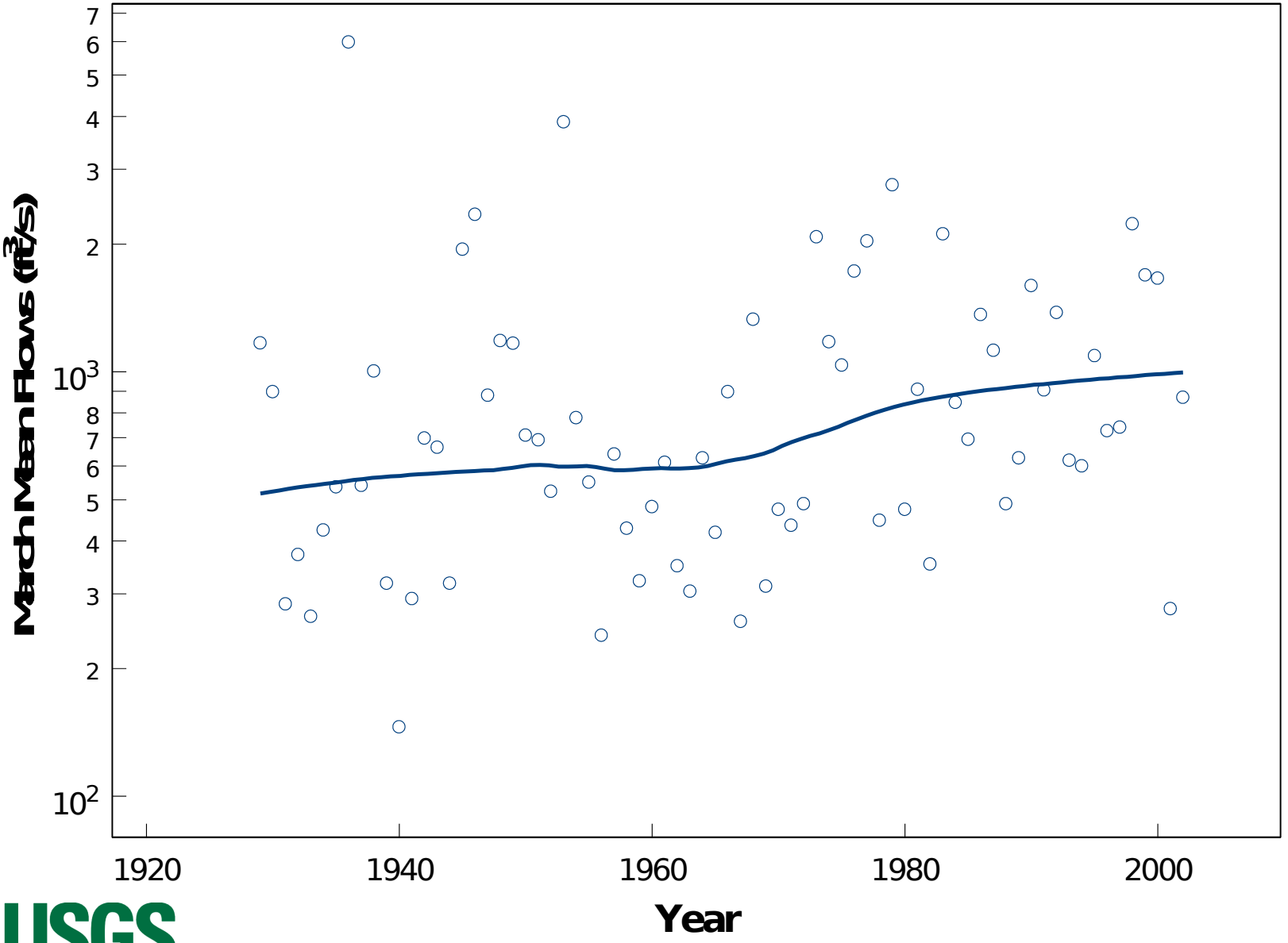
March Mean Flows

Saco River near Conway, New Hampshire



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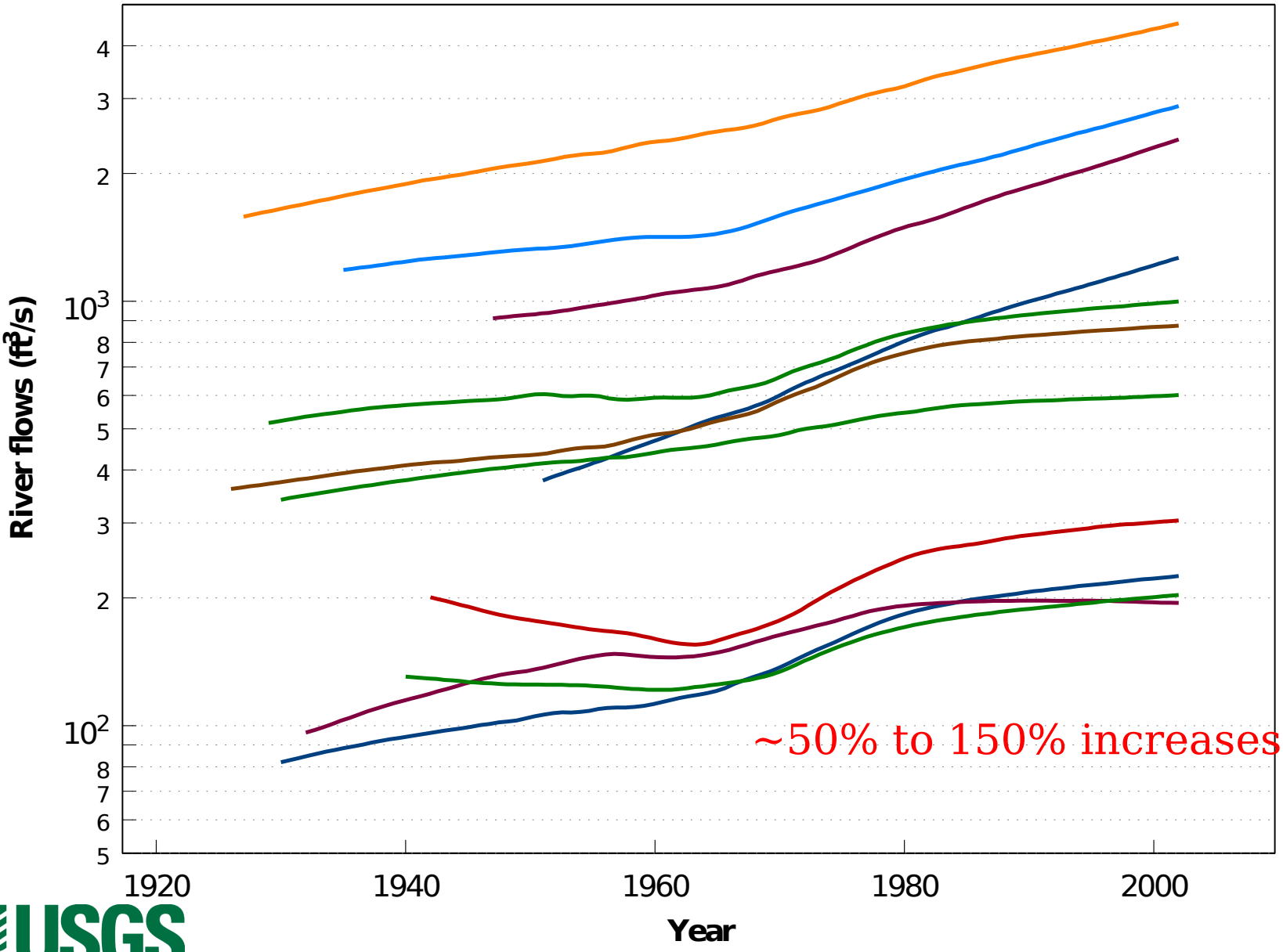
March mean flows for 11 rivers in northern and mountainous New England



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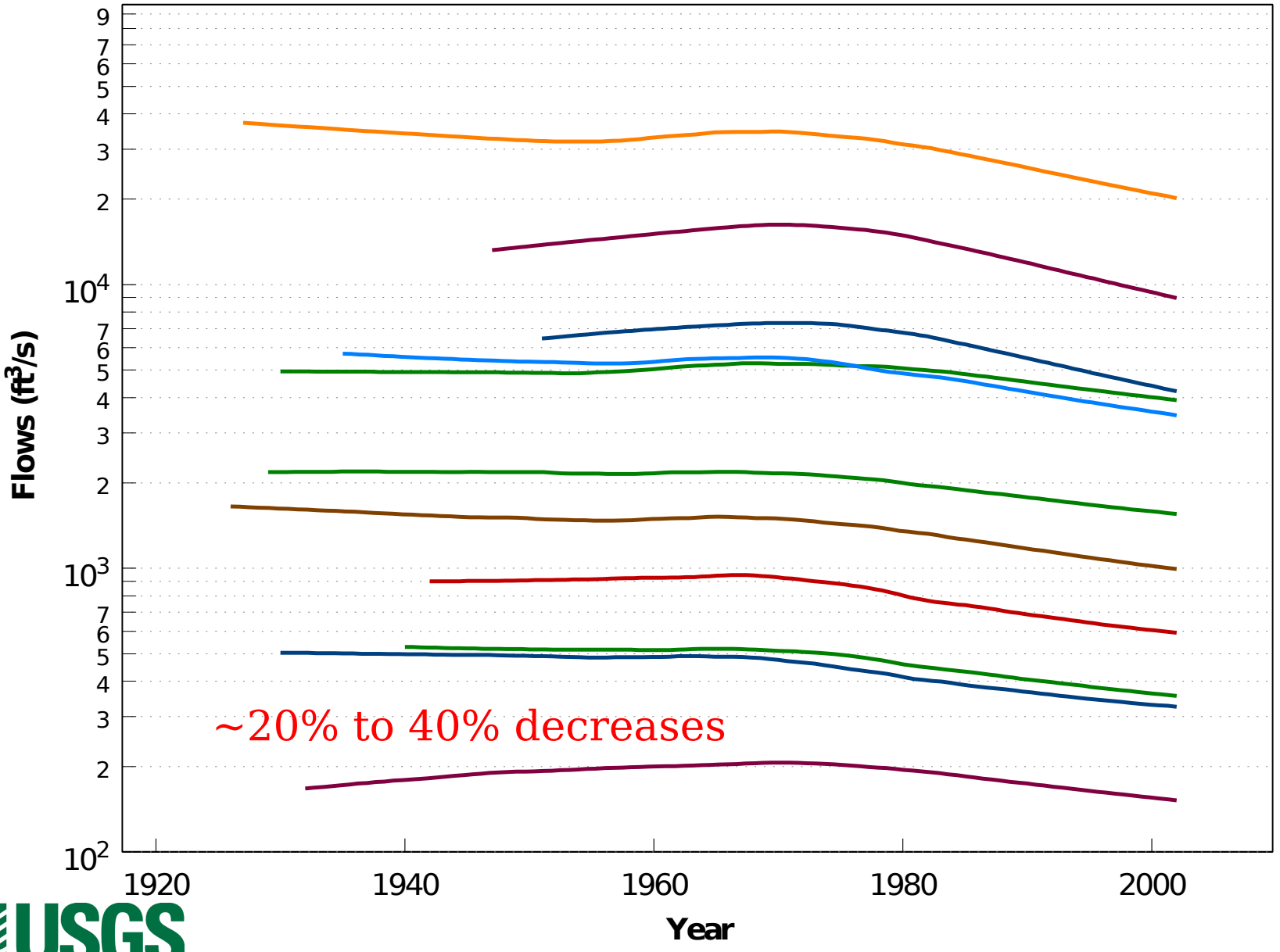
May mean flows for 11 rivers in northern and mountainous New England



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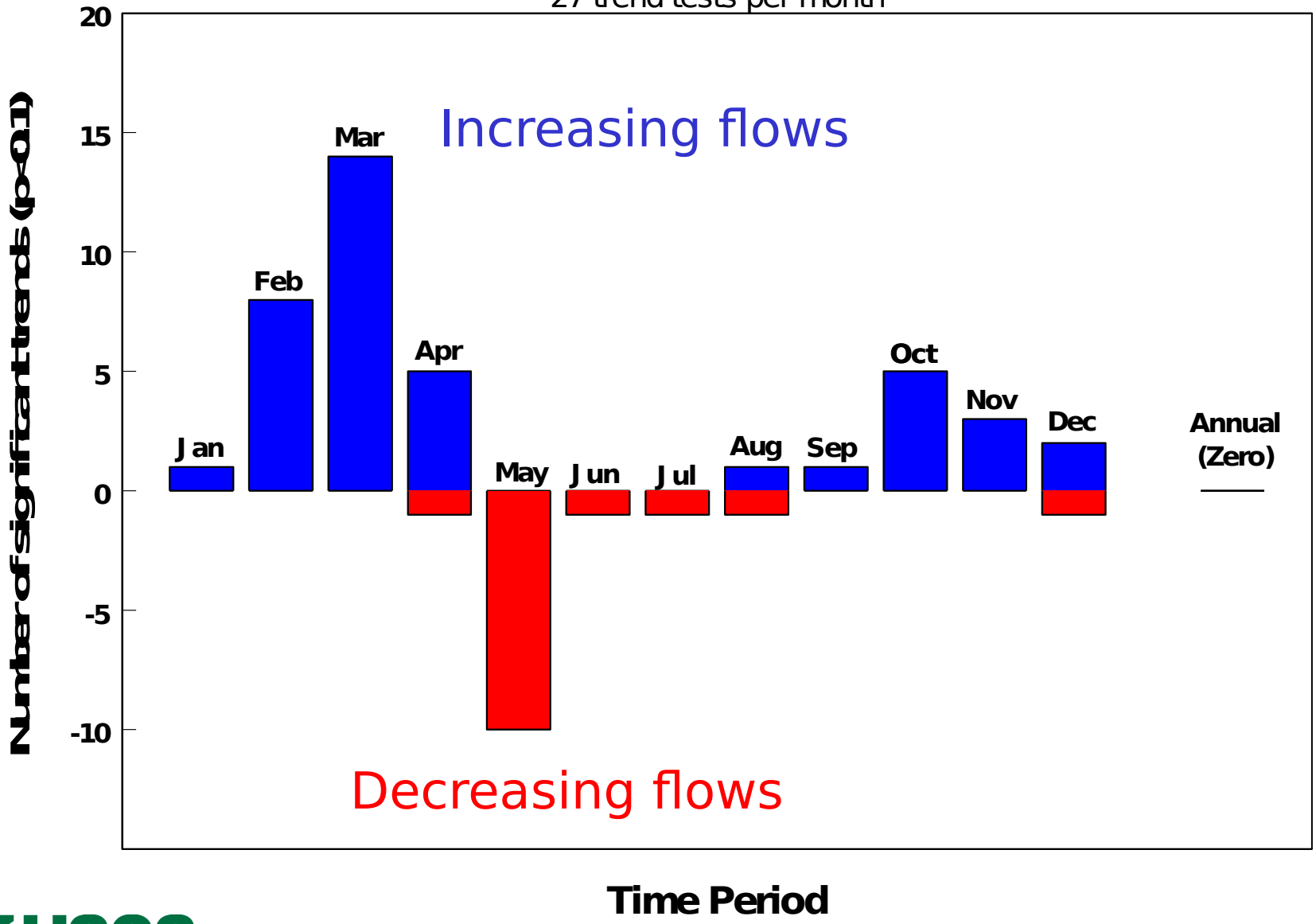
Number of significant trends for mean flows for all sites

27 trend tests per month



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Why are things changing in winter and spring in New England?

- Higher air temperatures and earlier snowmelt likely the primary cause
  - Earlier melting of snowpack
  - Higher rain to snow ratio
    - Huntington et al., 2004, Journal of Climate

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River and Lake data vs. Meteorological data (temperature and precipitation)

Highest correlations

- March-April air temps: r = 0.7
  - Lake ice-out dates
  - Last spring dates of ice-affected river flow
  - Timing of spring river flows

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Why are these changes important?

- Increase in winter river ice jams (Beltaos, J. Hydrol., 2002)
- Problems with summer water supply?
- Could endanger survival of Atlantic salmon (McCormick and others, 1998)
- Changes in lake stratification and of summer oxygen availability (Stewart, 1976)

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REFERENCES

Hodgkins, G.A., and Dudley, R.W., 2006, **Changes in the timing of winter-spring streamflows in eastern North America, 1913-2002**: Geophysical Research Letters, 33, L06402, doi: 10.1029/2005GL025593.

Hodgkins, G.A., and Dudley, R.W., 2006, **Changes in late-winter snowpack depth, water equivalent, and density in Maine, 1926-2004**: Hydrological Processes, 20, 741 - 751.

Hodgkins, G. A., and Dudley, R.W., 2005, **Changes in the magnitude of annual and monthly streamflows in New England, 1902-2002**, USGS Scientific-Investigations Report 2005-5135, 37 p.

Hodgkins, G.A., Dudley, R.W., and Huntington, T.G., 2005, **Summer low flows in New England during the 20th Century**: Journal of the American Water Resources Association, 41, 403-412.

Dudley, R. W., and Hodgkins, G. A., 2005, **Trends in timing, magnitude, and duration of summer and fall/winter streamflows for unregulated coastal river basins in Maine during the 20th century**: U.S. Geological Survey Scientific Investigations Report 2005-5021, 26 p.

Hodgkins, G.A., Dudley, R.W., and Huntington, T.G., 2005, **Changes in the number and timing of days of ice-affected flow on northern New England rivers, 1930-2000**: Climatic Change, 71, 319-340.

Hodgkins, G.A., Dudley, R.W., and Huntington, T.G., 2003, **Changes in the timing of high river flows in New England over the 20th Century**: Journal of Hydrology, 278, 244-252.

Dudley R. W., and Hodgkins, G. A., 2002, **Trends in streamflow, river ice, and snowpack for coastal river basins in Maine during the 20th century**: U.S. Geological Survey Water-Resources Investigations Report 02-4245, 26 p.

Hodgkins, G.A., James, I.C., and Huntington, T.G., 2002, **Historical changes in lake ice-out dates as indicators of climate change in New England, 1850-2000**: International Journal of Climatology, 22, 1819-1827.

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